HOW MUCH TO MAKE AND HOW MUCH TO BUY?

AN ANALYSIS OF PLURAL SOURCING STRATEGIES

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Abstract

While many theories of the firm seek to explain when firms make rather than buy, in practice firms often make *and* buy the same input- they engage in plural sourcing. We argue that explaining the mix of external and internal procurement for the same input requires moving away from individual transaction level analysis, to a consideration of complementarities across and constraints within modes of procurement. We thus create an analytical foundation for making empirical predictions about the extent of vertical integration for a given input (which is distinct from predicting whether a specific transaction is conducted within or between firms, or the scope of activities outsourced). Our framework also proves useful for assessing the possible biases in transaction level make-or-buy studies arising from ignoring complementarities and constraints.

Following the extremely productive research trajectory sparked by Coase's original insights, there is general consensus today that the boundaries of the firm matter- that making and buying are qualitatively distinct forms of governance and organization (Coase, 1937). Indeed, the make-or-buy problem has become central to theories that attempt to explain the nature, origin and boundaries of the firm. Transaction cost economics, a leading theoretical perspective on these issues, specifies whether firms choose to make or buy a key input as a function of the need for investments specific to the transaction, uncertainty about contract parameters, and frequency of transactions (Williamson, 1991a). Other theorists, while offering different explanations for the choices between make and buy, such as superior coordination and knowledge transfer within firms (Conner & Prahalad, 1996; Grant, 1996; Kogut & Zander, 1996), or information asymmetry and measurement costs (Barzel, 1982; Demsetz, 1988), nonetheless retain the discrete make-or-buy choice as the central empirical phenomenon to be explained.

Yet, firms often make *and* buy the same input (Bradach & Eccles, 1989; Harrigan, 1986). Such instances of plural sourcing- of firm simultaneously using multiple modes of procurement for the same input- have been well documented across a number of settings. Firms in the auto industry often both make and buy the same components (Gulati, Lawrence& Puranam, 2005), as do those in the metal works (Parmigiani, 2006) and the fashion garments industries (Jacobides & Billinger, 2006). Firms are also known to rely simultaneously on their own as well as external distribution channels (Dutta, Bergen& Heide, 1995; Heide, 2003), and combine chains of fully owned and franchised operations (Bradach, 1997; Lafontaine & Slade, 1997). Empirical studies of the make or buy problem often feature a dichotomous characterization of a procurement decision as make or buy based on some arbitrary cut-off (eg. more than 80% bought is defined as "buy" in the classic study of outsourcing in the auto industry by Monteverde and Teece, 1982),

reflecting the empirical reality that firms can and do choose both modes of transacting simultaneously.

While scholars increasingly recognize the existence of the plural governance form as well as agree broadly on the reasons for its existence (Bradach, 1997; Jacobides & Billinger, 2006; Parmigiani, 2006; Rothaermel, Hitt& Jobe, 2006), in this paper we will show that our ability to explain specific *plural sourcing strategies*- how much firms choose to make vs. how much they choose to buy – has remained limited. Perhaps surprisingly, arguments that explain the "make or buy" decision are logically insufficient to explain the extent of vertical integration- the proportion of volume for a product that a firm chooses to produce internally. Thus arguments for why a firm might be better off making than buying (for instance in the presence of anticipated hold-up) are insufficient to explain why the firm makes 80% of its requirements in-house but outsources the rest. Nor do arguments that explain the benefits of both making and buying (Bradach, 1997; Jacobides & Billinger, 2006) necessarily shed much light on how much firms make and buy. In other words, knowing that there are gains from both making and buying still leaves us uncertain as to why one firm may choose to produce 70% of its requirement internally and outsource 30%, while another firm does exactly the opposite.

In this paper we argue that to explain plural sourcing strategies - how much of their requirements firms meet through in-house production as opposed to external purchase- we need to account for non-linearities in the differential advantages of making and buying. As we will show through both verbal and formal arguments, the optimal mix of procurement depends on scale constraints to internal and external procurement as well as benefits (complementarities) from sourcing through multiple modes simultaneously. Further, we show how complementarities and constraints interact to shape the optimal mix of

procurement, and how they weaken the link between transactional attributes and governance choices as posited in traditional make or buy theories.

It is useful to clarify at the outset the distinction between plural sourcing and what are often known as "hybrids"- organizational forms that are distinct from in-house procurement and arms-length market relationships (Hennart, 1993; Powell, 1990; Williamson, 1991b). Hybrids are a mode of procurement that are different from either make or buy – they may not feature complete ownership, but may however be characterized by a degree of cooperation and coordination that is unusual in market relationships (Gulati, Lawrence and Puranam, 2005). They often embody greater authority and continuity of association than is found in market relationships, but also more reliance on prices than is typical for firms (Bradach and Eccles, 1989; Williamson, 1991a). Hybrids are "mixed modes" of procurement in the sense that they display governance characteristics that appear to combine price and authority (Bradach and Eccles, 1989; Hennart, 1993).

However, plural sourcing refers to a different phenomenon- a mixing of modes in the sense that firms may simultaneously rely on pure hierarchy (internal procurement) as well as price (market contracts) for the same input.[2] Thus, whereas hybrids refer to procurement of the *entire* volume from a single mode that exhibits mixed governance characteristics, plural sourcing refers to the splitting up of total volume being procured across multiple modes, each of which may be a pure governance mode. As we will argue in this paper, the rationale that motivates plural sourcing is quite distinct from that underlying the preference for hybrids over either making or buying. To keep our theorizing parsimonious, we will focus on plural forms that include simultaneously making and buying.

[2] We also distinguish our work from prior research that focuses on the extent of vertical integration in terms of the fraction of all inputs made in-house or the number of value chain activities involved in Eg. Rothaermel, Hitt and Jobe, 2006

In the next section, we first explain in detail why extant make-or-buy theories do not provide an adequate explanation for variations in plural sourcing strategies. In the following section, we propose a model of plural sourcing. In the fourth section, we derive novel implications from our model for both understanding plural sourcing as well as conducting empirical analysis of vertical integration strategies. The last section concludes with a discussion of implications for theory, empirical research and practice.

WHY MAKE-OR-BUY THEORIES DO NOT EXPLAIN PLURAL SOURCING STRATEGIES

Consider a canonical representation of transaction cost arguments found in Williamson's work (1991a). Figure 1 (based on Figure 1 pg 284 in Williamson's 1991 paper in the *Administrative Science Quarterly*) shows governance costs for a transaction when it is conducted within markets (M) and hierarchies (H) respectively as a function of the extent of asset specificity (*k*) involved. This is a graphical version of the "comparative cost/benefit" analysis first indicated by Coase (1937), and developed subsequently by Williamson (1985; 1991b). The figure shows that the governance costs are lower for markets than hierarchies at low levels of asset specificity, but higher in markets than hierarchies for high levels of asset specificity, implicitly holding the benefits from the exchange constant.

Insert Figure 1 Here

What is noteworthy is that the governance costs shown in Figure 1 are volume independent- they describe the relative costs of markets, hierarchies and hybrids whether a single unit of a good is being exchanged or a million units. If it is cheaper to use markets for the first unit of a good being procured, so it is for the millionth unit- within the logical framework represented by the figure, there is no reason why firms should procure some fraction of their requirement for a good (with a certain level of asset specificity) from the

market and make the rest internally. This picture makes clear that the traditional comparative cost/benefit analysis of transaction cost economics does not accommodate the possibility of plural sourcing- quite naturally, as that is not the emphasis of the theory.

Indeed, arguments from a transaction cost perspective suggest that many cases of plural sourcing may turn out to be quite different things being procured through different modes. For instance, Williamson (1985, pg 96) argues that when firms appear to be both making and buying the same good, a closer examination should reveal that the internally produced good actually involves higher asset specificity – what appear identical are in fact heterogeneous transactions. The claim therefore is that what appears on the surface to be a case of a firm procuring the same component through make and buy is actually the firm procuring two distinct components each being procured by the appropriate means.

An empirical illustration of this "transactional heterogeneity" argument can be found in a recent paper by He and Nickerson (2006) that examines why many interstate trucking companies engage in hiring their own drivers as well as relying on external drivers often for trips of comparable mileage and loads. The answer they propose is that not all load-miles are equal, thus suggesting that firms are not necessarily simultaneously making and buying the exact same thing. In the trucking industry a key profitability driver is the avoidance of empty backhauls. Orders that originate and terminate at company depots are economically different from orders that do not- even if the weight and distance are identical. Trucking companies therefore use their own drivers for orders of the former type, while outsourcing those of the latter type. Thus, once transactional heterogeneity is correctly accounted for, the "anomaly" of plural sourcing disappears (He & Nickerson, 2006).

We take a different perspective in this paper by offering a theoretical explanation for differences in the amounts that firms source internally or externally, on the assumption that they at least sometimes do engage in plural sourcing. Arguments about transactional

heterogeneity notwithstanding, as we noted in the introduction, the documented instances of firms procuring identical inputs from internal and external sources simultaneously are too numerous to be dismissed offhand (Harrigan, 1986; Bradach and Eccles, 1989; Parmigiani, 2006; Gulati, Lawrence and Puranam, 2005; Jacobides and Billinger, 2006). Put differently, how frequently plural sourcing occurs is an empirical question; however, as long as it does occur at all, there is potential value to a theory that explains how firms choose how much to make and how much to buy. This raises an obvious question- can we simply extend current theories about whether firms make or buy to explain how much firms make and buy?

It seems self-evident that it is not feasible to apply a logic that explains if a service or good is either made or bought, to the question of *how much* is made and *how much* is bought. For instance, the standard comparative cost logic of transaction cost economics cannot explain why some proportion of a good is made and some proportion simultaneously bought; it only allows for a prediction of the conditions under which all or none of it is bought (or made). Nor is it possible to invoke measurement/judgement errors to justify prediction about the extent of internal procurement. It might appear plausible to argue that when a firm makes 75% or 80% of its requirement for an input it can be interpreted to mean that the firm is in fact making 100% internally and the 20% represents errors of measurement or judgement on the part of management (Monteverde & Teece, 1982; Poppo & Zenger, 1998). However this leaves unanswered the question of why the extent of the error should be correlated inversely with transactional hazards.

Another approach sometimes taken by scholars to explain plural sourcing is to suggest that plural sourcing occurs when firms are just indifferent between making and buying (Parmigiani, 2006). This situation occurs in Figure 1 at asset specificity level of k* at which point firms are likely to be indifferent between the two discrete choices of make or

buy. One can also imagine scenarios where the effects of different transactional attributes cancel out the advantages of both market and hierarchical procurement so that a situation of indifference prevails. For instance, the level of asset specificity may be high but so may be the cost of bureaucracy borne if the transaction is integrated, making firms indifferent between their discrete choices. The "indifference hypothesis" can explain why in a cross section of firms engaging in identical transactions, some choose to make and other to buy. Further, this indifference hypothesis may also help explain hybrids- if the hybrid offers a governance-cost advantage over either market or hierarchy when transactional hazards and costs of bureaucracy are finely balanced. However, it cannot explain why any given firm should do both, nor the proportion it may source from each mode.

How then do we explain variation in plural sourcing strategies- how much firms choose to make and how much they choose to buy? In the next section we set up a simple formal model to help think through this question.

A MODEL OF OPTIMAL PLURAL SOURCING STRATEGIES

We formulate an optimisation model in which a decision maker chooses how much to make and how much to buy. Drawing on prior literature, we model how complementarities and constraints influence firms' decisions to simultaneously make *and* buy (see Table 1 for an overview of complementarities and constraints in procurement). In contrast to traditional comparative costs/benefit arguments (eg. the benefits of internalisation in the presence of transaction hazards) which explain whether firms make or buy, complementarities and constraints explain why firms might choose to do a bit of both (i.e. plural source), as well as variations across firms in how much they make and buy.

To clarify our discussion, it is helpful to refer to Figure 2 in which we visualize the firm's procurement choices. This figure shows the various possible combinations of proportions that a firm may choose to make (produce within itself) and buy (procure from

another firm i.e. the market). At the extreme left is the case where a firm buys its entire requirement for a particular input. At the extreme right is the case where a firm makes its entire requirements internally for a particular input.

Insert Figure 2 Here

Standard formulations of theories that explain make-or-buy decision by invoking the comparative cost/benefit logic can explain which of the two corner solutions (all make or all buy) would be adopted – the logic is one of forces that "push towards the corners". For instance, a net advantage in terms of governance costs in favour of make (for instance, because of asset specificity) would imply that firms make their entire requirements; a net disadvantage (for instance, due to extremely high costs of bureaucracy) would imply that firms choose to buy their entire requirements. Our goal is to propose a model that not only formalizes when firms engage in plural sourcing, but also specifies the optimal mix of how much they (should) make and how much they (should) buy.

The optimisation problem we formulate to gain insight into plural sourcing can be written as $\underset{x,y}{Minimise}\ C(x,y)\ s.t.\ x+y=q>0,\ x\geq 0,\ y\geq 0$. Here, x is the quantity of an input made in-house and y is the amount bought from an external source and C*(x,y)* is the total cost of procurement, which is to be minimized. We normalize $q=1$ so that *(x, y)* become the proportions made and bought respectively. A measure of the extent of plural sourcing is then given by $\rho\in[0,1/4]=x(1-x)$.

We write the total cost of procurement as

$$C(x,y)=xc(x,y)+yp(x,y) \qquad (1)$$

, where the average cost of internal production is $c(x,y)$ and the average price paid for external purchase is $p(x,y)$. These are assumed to take the following forms[3]:

[3] We also outline a more general version of the model in the Technical Appendix to the paper.

$$c(x, y) = (m - k_1 y + \frac{i}{2} x) \qquad (2)$$

$$p(x, y) = (b - k_2 x + \frac{e}{2} y) \qquad (3)$$

We explain the formulation in (2, 3) in detail below, with each kind of parameter dealt with separately. The parameters can broadly be classified into those that capture volume independent costs of procurement, and those that capture volume dependent costs. [4]

Volume independent average costs

The parameter $m(>0)$ captures the volume independent component of the average cost of producing each unit. This includes both production costs as well as any relevant governance costs (eg. the costs of bureaucracy). Similarly, the parameter $b(>0)$ captures the volume independent component of the average price paid per unit for purchasing from an external supplier. Again this includes both the exchange price as well as any relevant governance costs (eg. the transaction costs of exchange with an external supplier). Thus, all else being equal, the existence of substantial transactional hazards and an advantage for internal procurement over external procurement would be captured by $b - m > 0$. Henceforth, we will refer to $\delta = b - m > 0$ as a measure of transactional hazards to ease exposition, while fully being aware that there are other reasons for $\delta > 0$ (for instance lowered costs of internal production due to superior coordination and knowledge transfer with an internal supplier) as well as being open to the possibility of $\delta < 0$ (for instance, due to very high levels of bureaucratic costs or simply very high levels of scale economies, giving the advantage to specialist external suppliers in terms of production costs).

Complementarities across procurement modes

[4] We show in the Technical Appendix that additive separability of these two kinds of costs, as assumed in (2) and (3) is not critical to our results.

The parameters $k_1, k_2 (> 0)$ capture complementarity effects between the two modes of procurement. Complementarities refer to a situation in which the performance consequences of a choice depend on other choices (Milgrom & Roberts, 1990; Milgrom & Roberts, 1995). In formal terms, this is often expressed as the marginal value of one variable depending on the value of another variable (Siggelkow, 2002). The notion of complementarity recurs under various guises as "interdependence" (Thompson, 1967), "fit" (Drazin & van de Ven, 1985) or "synergies" (Markides & Williamson, 1996) in the literature on organizations and strategy (Milgrom and Roberts, 1995). In the context of plural sourcing, complementarity refers to the condition in which the marginal benefit of procuring a good from the market depends on the level of in-house production, and vice versa. In the words of Bradach and Eccles (1989), "transactions controlled by one mechanism are profoundly affected by the simultaneous use of an alternative mechanism". We note that by their nature, complementarities are systemic- the gains are most accurately assessed at the level of the "system" defined by the choices, rather at the level of each individual choice (Milgrom and Roberts, 1995). Thus complementarities between procurement modes should enhance the performance of the firm, or more precisely the business unit that engages in plural sourcing.

By definition, complementarity effects are volume dependent, in the sense that k_1 scales the reduction in the average costs of internal production for every unit of external production, and k_2 captures the reduction in average prices paid to external suppliers with every additional unit of internal production. The mechanisms underlying such complementarity effects have been noted by several observers of procurement strategies, and can be broadly classified into "incentive" and "knowledge" categories (also see Table 1).

The key mechanism underlying incentive complementarities is competition. By creating implicit or even explicit competition between internal and external units, the procuring firm enjoys the benefits of stronger incentives acting on both kinds of suppliers. One of the earliest explanations for plural sourcing hinged on the incentive complementarity argument that if firms both made and bought an input, it gave them the ability to credibly threaten backward integration to their suppliers (Porter, 1980). Harrigan's work (1985; 1986) documented specific instances of this form of plural sourcing, adding texture to the concept described by Porter (1980). A related incentive based advantage to plural sourcing is that internal production can give firms superior insight into performance measurement and costs, enabling enhanced monitoring and measurement of their external suppliers (Dutta et al., 1995; Harrigan, 1985, 1986; Heide, 2003). Equations (2) and (3) also capture the intuition that that increasing levels of production in one mode increase both the credibility of the threat of replacing production in the other mode as well as the effectiveness at monitoring it.

In contrast with incentive complementarities, knowledge complementarities refer to improvements in the competence of internal suppliers because of procurement from external suppliers and vice versa. Knowledge complementarities in procurement can arise whenever the knowledge generated in each mode of procurement is distinct from the knowledge generated in the other mode, but is usable in both (Sorensen and Sorenson, 2001). The mechanism underlying such complementarities is collaboration (not competition) between internal and external suppliers in order to create value for the procuring firm. Firms can benefit by their internal and external suppliers sharing their individually generated knowledge of improvements in production processes and technologies, thus enabling each other to enhance their efficacy and effectiveness.

It is of course critical that collaborative mechanisms exist for the exchange of knowledge between internal and external suppliers, as the movement of knowledge across the boundaries of the firm is not easy (Kogut and Zander, 1992). Bradach's analysis of plural forms in franchising underlines the importance of formal mutual learning processes for knowledge complementarities to be exploited (Bradach, 1997). Despite the deep difficulties posed by knowledge transfer across firm boundaries, scholars have documented instances of firms effectively exchanging the knowledge underlying such performance improvements both within and between themselves (Dyer & Hatch, 2006; Dyer & Singh, 1998; Hatch & Dyer, 2004; Helper, MacDuffie& Sabel, 2000).This suggests that knowledge complementarities can vary in their magnitude by setting rather than being all or nothing.[5] As with incentive complementarities, it seems intuitive that the extent of knowledge produced in each mode that is valuable to the other should bear an increasing relationship to the volume procured in that mode, and this is captured in equations (2) and (3).

A more subtle form of complementarity that mixes incentives and knowledge occurs through a process that has been described as "ratcheting" (Bradach, 1997). In situations where a firm engages in plural sourcing, it is often possible for it to use the performance achieved in one mode as the standard for the other. For instance, franchisee and company owned fast food restaurants frequently benchmark their performance against each other. The effect goes beyond just the maintenance of current standards, to include a virtuous cycle of continuous improvement as internal and external supplier compete against the performance benchmarks established by the other (and inevitably overshoot).

[5] Since knowledge based complementarities appear to rely on collaboration, whereas incentive complementarities arise from competition between internal and external suppliers, it is tempting to conclude that the two are mutually exclusive. Yet, there is sufficient evidence that relationships with suppliers tend to have elements of both competition and collaboration, so that it is possible for the two sources of complementarity to co-exist (Helper et al, 2000; Helper and Mudambi, 1996).

The two complementarity parameter $k_1, k_2 (> 0)$ can be treated equivalently in our analysis. To see this, we can write out the total procurement cost function (1) into two components: the total cost of internal procurement (making) and the total cost of external procurement (buying) as follows:

$$C(x, y) = C_M(x, y) + C_B(x, y),$$
$$where\ C_M(x, y) = xc(x, y) = x(m - k_1 y + \frac{i}{2} x),$$
$$and\ C_B(x, y) = yp(x, y) = y(b - k_2 x + \frac{e}{2} y)$$

Now, the marginal cost of making (x) is given by $\frac{\partial C_M}{\partial x} = m - k_1 y + ix$, and the reduction in this marginal cost by an extra unit of procurement (y) is $\frac{\partial^2 C_M}{\partial y \partial x} = k_1 > 0.$ In the same way, $k_2 > 0$ measures the reduction in average price paid for buying for every unit increase in internal procurement, i.e. $\frac{\partial^2 C_B}{\partial y \partial x} = k_2 > 0.$ The overall strength of complementarity is $\frac{\partial^2 C}{\partial y \partial x} = \frac{\partial^2 C_M}{\partial y \partial x} + \frac{\partial^2 C_B}{\partial y \partial x} = k_1 + k_2 > 0.$ Therefore, when our arguments do not require us to distinguish the strength of the complementarity arising from internal production leading to reduction of average price or purchase leading to reduction of average internal procurement cost, we write $k_1 + k_2 = \theta$.

While much of the prior discussion of plural sourcing has been asymmetric in the sense that the emphasis was on the benefits of some internal production for managing external suppliers (Porter, 1980; Harrigan, 1985) i.e. k_2, more recently, researchers have explicitly recognized the complementarity can work both ways- participation in the external markets also helps to discipline the internal provider i.e. k_1. "Placing an outside order, over and above the transactional and cost considerations can be seen as an investment that

infuses the firm with discipline through its active participation in intermediate markets" (Jacobides and Billinger, 2005: pg 256). Indeed the same argument can be made for the threat of backward integration- just as an internal supplier threaten vendors with backward integration, an external supplier can be the basis for a firm providing a credible threat to its internal unit with divestment and outsourcing in the event of poor performance. However, as our formulation clearly shows the magnitude of the two effects need not be identical ($k_1 \neq k_2$).

Scale constraints to internal and external procurement

The parameters $i, e(>0)$ capture scale constraints arising from increasing marginal costs to internal and external procurement respectively. Thus, i indicates the strength of the "limits to scale" constraint, so that ix is the increasing marginal cost of procuring internally. Diseconomies of scale in production are a standard assumption in neoclassical economics, and underlie the upward sloping portions of long run average cost curves (Pindyck and Rubenfeld, 1995). The source of these diseconomies often lies in the limits of organization (Arrow, 1974). Administrative limits to scale can arise from pure coordination failures as well as from motivation losses.

A dramatic illustration of scale diseconomies that arise purely from coordination complexity is provided in the experimental research on coordination games (Camerer, 2003). A series of studies have shown that in the weakest link game (a pure coordination game with symmetric equilibria that can be Pareto ranked), coordination failures increase dramatically with the size of the team playing the game (Weber, Camerer, Rottenstreich& Knez, 2001; Weber & Camerer, 2003). This is due to the combinatorial increase in the number of other players with whom one must share convergent expectations in order to select the efficient equilibrium.

The effects on motivation of increasing group size are well known. Free riding is the tendency of individuals to shirk group activities, as their marginal returns are not large enough to offset their marginal costs of efforts. The marginal returns decrease with group size, so that free riding problems worsen with increasing (Holmstrom, 1982; Kollock, 1998). With increasing group size, each individual also bears greater risk as the outcome is increasingly determined by others whom that individual may have little control over, so that effective incentive intensity is reduced (Baker, 2002).

Another well-known source of diseconomies to scale arises from volume uncertainty coupled with costs of excess capacity (Porter, 1980; Harrigan, 1986). With fluctuations in demand, firms are exposed to periods of excess capacity if they choose to invest in production for peak demand (Pindyck & Rubenfeld, 1995). If the cost of this excess capacity is significant, then the firm may optimally choose to produce at lower scale (Balakrishnan and Wernerfelt, 1986). In our model, the larger i is, the more significant the diseconomies of scale that impose constraints on internal production.

Similarly, the parameter e can be interpreted as indicating the strength of the "limits to scale" in external procurement, so that ex is the increasing marginal cost of purchasing externally. However, the increasing marginal costs of external purchase may not arise from the inability of suppliers to provide at larger volumes, but rather because of the increasing difficulty firms may face in terminating internal production. Barriers to exit may exist because of reputation or commitment lock-ins (Ghemawat, 1991). In effect, maintaining uneconomical in-house production may be necessary to sustain reputations or honour commitments made to various stakeholders (or even competitors). Employment contracts, public commitments, regulation and pressures from unions may prevent firms from completely exiting production even when it is clearly more economical to procure from the market, with the level of resistance increasing with greater levels of outsourcing.

More generally, constraint on a firm's governance choices arising from choices in prior periods is known as governance inseparability (Argyres and Liebeskind, 2002), and barriers to exit from internal production or limits to scaling internally because of prior commitments to external suppliers are instances of such inseparability.

We note that there are other limits to scale and barriers to exit that may not however manifest themselves as increasing marginal costs of in-house production or external procurement. For instance, the simplest economic rationale for barriers to exit may arise when fixed costs take on the form of sunk investments. Under such circumstances, it may be rational to continue in-house production because the variable costs are lower than that of the average costs associated with procuring externally. However, this does not tell us what the ratio of internal to external production should be- as it only indicates a preference for in-house production. This rationale therefore falls into the class of explanations that help understand, at the transaction level, whether a particular transaction is conducted internally or externally- but not the proportions of internal and external procurement. In contrast the effects we are interested in are volume dependent, as they feature increasing marginal costs of in-house and external procurement- which therefore help to explain the extent of each kind of procurement.

EXPLAINING PLURAL SOURCING STRATEGIES

Solving for optimal levels of internal and external procurement by minimizing total costs of procurement (1), we obtain

$$x^* = \frac{e + (k_1 + k_2) + (b - m)}{e + i + 2(k_1 + k_2)} \qquad (4)$$

$$y^* = 1 - x^* = \frac{i + (k_1 + k_2) - (b - m)}{e + i + 2(k_1 + k_2)} \qquad (5)$$

We simplify notation by writing $(k_1 + k_2) = \theta, \quad (b - m) = \delta$. Further, to ease exposition, we ignore for the moment differences in the *relative* magnitude of the two constraints- limits to

scale and barriers to exit- and set $i = e = s$. While the two constraints appear to work in opposite ways (i.e. limit external vs. internal procurement) they both in fact serve to increase the tendency towards plural sourcing. Put differently, both are constraints on pure sourcing strategies, so that it is intuitive to combine both effects into one parameter.[6] Thus, we have three variables: δ, the volume-independent net advantage of internal procurement, θ, a measure of complementarities and s, a measure of constraints. We write our results in terms of these three parameters.

Simplifying (5) in this way yields:

$$x^* = \frac{1}{2} + \frac{\delta}{2(s+\theta)} \quad \text{and} \quad y^* = 1 - x^* = \frac{1}{2} - \frac{\delta}{2(s+\theta)} \tag{6}$$

These expressions capture the intuition that when $\delta = (b - m) > 0$ i.e. when there is a scale independent cost advantage to internal procurement, then in fact the majority of procurement will be internal ($x^* > \frac{1}{2}$), though a corner solution will not be reached because of the presence of complementarities $\theta > 0$ and constraints $s > 0$. In other words, plural sourcing results when

$$s + \theta > \delta > -(s + \theta) \tag{7}$$

or to write this in terms of the two different constraints, when

$$i + \theta < \delta < (e + \theta) \tag{7'}$$

else we obtain corner solutions (all make or all buy).

The optimal extent of plural sourcing is thus given by

$$\rho^* = x^* y^* = \frac{1}{4} - \left[\frac{\delta}{2(s+\theta)}\right]^2 \tag{8}$$

Model properties

[6] We later expand on the conditions under which this assumption may be inappropriate.

To begin with, we verify basic model properties, to confirm that the model captures the spirit of our intuitions about the problem accurately.

We first consider the conditions under which plural sourcing occurs. From (2, 3), it is clear that in the absence of complementarity and constraints (i.e. $e = i = k_1 = k_2 = 0$), x^* is always a corner solution with $x^* = 1$ if $\delta > 0$, and $x^* = 0$ if $\delta < 0$. This corresponds to the basic transaction cost injunction- produce internally in the presence of transactional hazards (i.e. $\delta > 0$) else buy. From (7), it is equally clear that the mere presence of complementarities and constraints is insufficient to encourage plural sourcing. Unless the non-linearities in the total cost of procurement created by constraints and complementarities (s, θ) are strong relative to the volume independent component – the transactional hazards (δ) - we always obtain corner solutions- all make or all buy. However, with strong non-linearities (as captured in equation 7), we obtain plural sourcing. Lastly, strong complementarities or strong constraints are individually sufficient to encourage plural sourcing.

Next, we verify how complementarities act in the model. We have argued that both knowledge and incentive complementarities have systemic effects in that they enhance the procuring firms performance for those inputs when plural sourcing rather than a pure procurement mode is used for them. Complementarities thus create a force that "pulls towards the middle" and away from a corner solution where a firm uses one or the other way of sourcing an input. Yet, it seems unlikely that plural sourcing will always involve an even split between internal and external procurement. For instance while making 10% of the requirement of a product internally may enhance the value of the 90% bought from the market (by transferring best practice to the supplier and/or monitoring the supplier better), it seems less clear that firms would make 50% internally in order to obtain these benefits.

This apparent conundrum is resolved once we factor in the basic comparative cost logic. Assume that on a per unit basis, buying is superior to making because production assets are not specific, and costs of bureaucracy are significant. Then, even if there are complementarities between making and buying arising from either knowledge or incentive considerations, there is a natural limit to how much the firm will make to leverage these complementarities, because the gain from complementarities must be offset against the costs of procuring more volume from the less efficient mode (on a per unit basis). In more technical terms, while making and buying may be complementary, the marginal rate of technical substitution between the two may not be equal to one.

Our model also provides a sound analytical basis on which to predict the extent of vertical integration- the proportion of volume of a product produced internally- on the basis of traditional arguments for make or buy. Thus, our model allows the prediction that transactional hazards ($\delta > 0$) increase the extent of vertical integration, whereas in the traditional comparative cost logic of transaction cost economics, it is only logical to predict that the firm would produce its entire requirements internally.

Finally, we note that the (sufficiently strong) constraints imposed by limits to scale and barriers to exit are an independent explanation for plural sourcing (besides complementarities). Intuitively, they are also useful to predict the extent of vertical integration (x^*) - with limit to scale discouraging and barriers ton exit encouraging greater levels of vertical integration.

We now progress to deriving propositions about how complementarities and constraints jointly shape optimal plural sourcing strategies. To the extent we can assume

optimising behaviour by decision makers, our model also provides predictions about the extent of vertical integration/plural sourcing we are likely to observe in data.[7]

How complementarities and constraints jointly shape optimal plural sourcing strategies

We take as the baseline the existence of transactional hazards ($\delta > 0$), which indicates a bias towards vertical integration ($x^* > \frac{1}{2}$ from 6). This helps us state our results in the intuitive terms of "how complementarities and constraints influence the relationship between transactional hazards and the extent of vertical integration". Note that while we discuss transaction hazards, the argument applies to any factors that create a procurement advantage for internal over external procurement (such as interdependence, information asymmetry, or measurement uncertainty).

Taking the appropriate derivative, we get:

$$\frac{\partial^2 x^*}{\partial \delta \partial \theta} = \frac{-1}{2(s+\theta)^2} < 0 \qquad (9)$$

This result shows that complementarities weaken the marginal effect of transactional hazards on the extent of internal procurement. To see why this should be the case, consider that an optimal choice will balance the gains from procuring from the more efficient mode on a per unit basis (say internal production) against the complementarity with external procurement. Within the model, an increase in the magnitude of complementarity will therefore have to be "met" by an increase in the magnitude of transactional hazards to maintain the balance at the equilibrium level of internal procurement. Therefore, for higher levels of complementarity, a higher level of

[7] Alternatively, managers might choose a particular sourcing strategy based on a variety of reasons unconnected with the theory – yet only those decisions that are "appropriate" given the levels of complementarities and constraints will perform well (and hence be observed) in the face of adequate competitive selection pressures. In other words, if managers make poor governance choices for their exchange relationships, such relationships will perform poorly relative to competition, and may not survive (Williamson, 1985).

transactional hazard is necessary to evoke the same optimal choice of internal procurement levels. Thus, as the level of complementarities increase, the marginal effect of transactional hazards on the extent of internal procurement declines. Thus, complementarities (which can arise either form knowledge or incentive considerations) negatively moderate the effect of transactional hazards on the extent of internal procurement. We formalize this as follows:

P1: Complementarities between internal and external procurement modes negatively moderate the relationship between transactional hazards and the extent of internal procurement.

Next, we investigate the effect of constraints on the relationship between transactional hazards and the extent of vertical integration. Taking the appropriate derivative, we get:

$$\frac{\partial^2 x^*}{\partial \delta \partial s} = \frac{-1}{2(s+\theta)^2} < 0 \qquad (10)$$

In this expression, we do not distinguish between the two kinds of constraints- on internal and external procurement. Rather, we investigate the impact of raising the magnitude of either kind of constraint- limits to scale or barriers to exit- on the relationship between transactional hazards and the extent of internal procurement. As (10) shows, we find that constraints, like complementarities, weaken the relationship between transactional hazards and the extent of internal procurement. It is interesting to note that while each kind of constraint may have a different kind of effect on the extent of internal procurement (i.e. limits to scale reduce the extent of internal procurement whereas barriers to exit increase it), both act in the same way to weaken the link between transactional hazards and the extent of internal procurement.

To understand this in the context of the model, note that an optimal choice will balance the gains from procuring from the more efficient mode on a per unit basis (say

internal procurement) against the costs imposed by constraints. Within the model, an increase in the magnitude of constraints will therefore have to be "met" by an increase in the magnitude of transactional hazards to maintain the balance at the equilibrium level of internal procurement. Therefore, for higher levels of constraints, a higher level of transactional hazards is necessary to evoke the same optimal choice of internal procurement levels. Thus, constraints arising from limits to scale or barriers to exit negatively moderate the effect of transactional hazards on the extent of internal procurement. We formalize this as follows:

P2: Constraints imposed by limits to scale and barriers to exit negatively moderate the relationship between transactional hazards and the extent of internal procurement.

Some interesting corollaries to the previous results can be easily derived by noting that (9) and (10) can be re-written as:

$$\frac{\partial^2 x^*}{\partial(-\delta)\partial s} = \frac{\partial^2 x^*}{\partial(-\delta)\partial \theta} = \frac{1}{2(s+\theta)^2} > 0 \qquad (11)$$

Thus, while complementarities and constraints weaken the positive association between transactional hazards and the level of vertical integration, they also weaken the *negative* association between volume independent factors that favour external procurement over internal production and the extent of internal procurement. Put differently, in the presence of complementarities and constraints, firms will make less than one would expect purely from transaction hazard considerations; and would make more internally than one would expect purely from considerations of volume independent cost advantages to external procurement. Thus, to the extent that there are complementarities across internal and external procurement modes, arising from knowledge or incentive considerations, then transactional hazards may appear to have limited or no effects on the extent of vertical integration. Similarly, to the extent there are constraints such as limits to scale and barriers

to exit, then transactional hazards may again appear to have limited or no effects on the extent of vertical integration. Therefore when complementarities and/or constraints are omitted variables, we can expect a conservative bias in estimating the relationship between transaction hazards (such as asset specificity and/or demand uncertainty) and the proportion of an input procured internally. Interestingly, the bias becomes weaker as the magnitude of complementarities and constraints increase (9 and 10). [8]

Finally, we consider how constraints and complementarities interact with each other in determining the mix of procurement from internal and external sources. The appropriate derivative is:

$$\frac{\partial^2 \rho^*}{\partial s \partial \theta} = \frac{-3\delta^2}{2(s+\theta)^4} < 0 \qquad (12)$$

As we have noted in the section on model properties, both complementarities and constraints encourage plural sourcing. However, as (12) shows complementarities negatively moderate the effect of constraints on the extent of plurality. In the presence of constraints, the marginal effect of complementarity on the extent of plural sourcing declines. This is because an optimal mix of procurement from internal and external sources will balance the gains from complementarities from splitting procurement volume across governance modes, against the costs imposed by sourcing additional volume from each mode (constraints). An increase in the magnitude of complementarity will therefore have to be "met" by an increase in the magnitude of constraints to maintain the equilibrium at the optimal mix of procurement. [9] Therefore, for greater magnitudes of complementarity,

[8] Interestingly, if there exists a relationship of substitution between internal and external procurement (rather than complementarity), then in fact the marginal effect of transactional hazards on the extent of internal procurement will be over-estimated- there could be an aggressive bias. We do not explore this in greater detail because of the absence of prior theory suggesting such a substitution effect.

[9] Note that given our assumption of $i=e=s$, this amounts to an assumption that not only both constraints are equally strong, each is also being increased equally. For the case of unequal changes to the two constraints, please see Technical Appendix.

constraints of greater magnitude are "necessary" to evoke the same optimal mix of procurement levels. Thus, complementarity negatively moderates the effect of constraints on the extent of plural sourcing. [10]We formalize this as follows:

P3: Complementarities negatively moderate the effect of constraints on the extent of plural sourcing.

CONCLUSIONS

Firms are more likely to make *and* buy rather than make *or* buy in the presence of complementarities and constraints. The tendency towards procuring from both internal and external suppliers is enhanced by complementarities and constraints, but suppressed by the existence of factors that create an advantage for one of the modes over the other. Our analysis goes beyond clarifying the role of constraints and complementarities to examine how these two might interact with transactional hazards and each other. We show that both constraints and complementarities weaken the relationship between transactional hazards and internal procurement. We also show that the joint effect of constraints and complementarities on the extent of plural sourcing can be weaker than the sum of their independent effects- they may interact as substitutes (a negative moderation effect) (please see Technical Appendix for additional boundary conditions on these results).

Our analysis offers a closer look at the assumption of mutual exclusivity of procurement modes implicit in the phrase "make or buy". Building on prior work on plural organizational forms (Bradach, 1997; Bradach & Eccles, 1989) and the benefits of plural sourcing (Porter, 1980; Harrigan, 1986; Parmigiani, 2006; Jacobides & Billinger, 2006) we proposed an integrated framework to explain how complementarities and constraints encourage plural sourcing and shape the optimal mix of internal and external procurement.

[10] Of course, it is analytically perfectly valid to also state that constraints negatively moderate the effect of complementarities on encouraging plural sourcing.

Our analysis suggests that while factors that confer a cost or benefit advantage to one of the modes of procurement (such as transactional hazards) push towards a pure sourcing model, constraints push firms away from corner solutions while complementarities pull towards equal usage of the two procurement modes. The combination of these forces determines the optimal mix of internal and external procurement. Our analysis thus offers a rigorous basis for explaining not only why firms make and buy, but also how much they make and buy (under assumptions of optimal decision making). Critically, the framework we provide enables predictions about the extent of vertical integration (i.e. the fraction of an input's requirements met internally) – something that prior theory was not configured to address.

The theory developed in this paper complements traditional transaction cost theorizing, or indeed any other theory that treats make or buy as mutually exclusive options, by specifying the conditions under which firms make and buy as well as how the optimal mix varies. Empirical analysis of transaction cost predictions can also be significantly refined by taking into account the existence of constraints and complementarities, both of which weaken the link between per unit cost/benefit considerations and procurement choices. In addition to correcting for these potential conservative biases, the inclusion of measures of constraints and complementarities help to explain when firms engage in plural sourcing as well as the mix of procurement modes they will adopt, neither of which is possible within the traditional transaction cost framework.

Perhaps the single most important insight to arise from a consideration of plural sourcing is the value of systemic firm level analysis as opposed to transactional level analysis. Our arguments have been developed from the perspective of a procuring firm that is considering choices about how much to make and buy, rather than a transaction level analysis about whether to make or buy an input. Shifting the level of analysis in this way leads to different predictions about transaction level choices. In the first place, it is possible

to specify the extent being procured from each mode. More important, this also leads to predictions about the optimal levels of procurement from each mode that are different from those generated by a consideration of transactional hazards or similar factors alone. As we have noted, in the presence of complementarities and constraints, firms should be optimally less responsive to transactional hazard considerations in choosing the extent of internal procurement. We thus see our analysis as opening an opportunity to move from transaction level strategy to an analysis of the portfolio of sourcing options, which may also be closer to the realities of managerial practice (Bradach and Eccles, 1989; Jacobides and Billinger, 2006).

Our analysis also suggests several fruitful areas for further research. In the interests of simplicity, our analysis has focused on plural sourcing with only two pure alternatives- make and buy. However, it seems feasible to extend the logic of our discussion to cases where a third alternative- alliance - is included. The precise mix of procurement volume across make, buy and ally would be somewhat harder to evaluate, as a continuum with two poles now becomes tri-polar; but the basic logic should remain similar. For instance, the comparative cost-benefit logic might indicate a more hierarchical mode of governance as asset specificity increases. The existence of knowledge or incentive complementarities should however cause firms to "distribute" their procurement across other modes as well, as would constraints.

It is also worth noting that the drivers of plural sourcing are distinct from those that motivate the selection of hybrids (such as alliances) over spot-market relationships and hierarchies. Within the transaction cost framework, hybrids become attractive relative to the poles for intermediate levels of transactional hazards (Williamson, 1991a; Gulati et al, 2005). However, plural sourcing does not lie intermediate between making and buying- it instead involves both. Intermediate levels of transactional hazards therefore cannot explain

plurals sourcing though they may explain the preference for hybrids. Conversely, complementarities or constraints cannot explain the preference for hybrids-which have governance characteristics intermediate between internal and external procurement. The drivers of plural sourcing and of the choice of hybrid governance forms are therefore distinct. This is a proposition that suggest a fruitful line of empirical investigation.

In theorizing about the possible interactions between procurement modes, we have drawn on prior research to focus on possible complementarities – situations in which procurement in one mode enhances the value of procurement from the other. However, it is theoretically possible that the interaction is one of substitution- where procurement from the internal supplier in fact decreases the marginal value of procurement from the external supplier – though such instances have not yet been systematically studied empirically. The formal analysis we conducted is however easy to modify for such possibilities. A key insight is that in the case of substitutive interactions between procurement modes (eg. the use of external procurement demotivates internal suppliers instead of spurring competition and enhanced incentives for them), ignoring such interactions can create an upward bias in empirical estimates of the strength of the relationship between transactional hazards and internal procurement.

We believe our research makes an important contribution to the literature on organizational form and procurement modes. By providing a theoretical framework to explain the occurrence and extent of plural sourcing, we extend existing theory and also bring a phenomenon that has often been treated as "noise" surrounding make or buy decisions, into the domain of systematic analysis. In some of the early work on this topic, Bradach and Eccles noted that "Explanations for when and why different mixtures of control mechanisms occur need to be developed. Such explanations may end up consistent with existing theories such as transaction cost economics. Little progress will be made,

however, unless we step away from the theoretical baggage which insists that we view markets and hierarchies as mutually exclusive alternatives…." (1989; pg 116). It is heartening to notice that the topic of plural sourcing has begun to attract scholarly attention again (He and Nickerson, 2006; Parmigiani, 2006; Jacobides and Billinger, 2006) after a long hiatus (Porter, 1980; Harrigan, 1985; Bradach and Eccles, 1989). Yet much undoubtedly remains to be done. We hope to have provided a rigorous, integrated theoretical foundation for making further progress on the fascinating question of why firms both make and buy Further, by considering the interactions between different modes of procurement, a more accurate picture of the boundaries of the firm may emerge, with due recognition that while individual transactions may lie squarely within or between firms, production activity as a whole may be less easily (and indeed, usefully) classified in this dichotomous manner.

Technical Appendix

1. General formulation of model and its properties

The optimization problem can be written as

$$\underset{x,y}{Minimise}\ C(x,y)\ s.t.\ x+y=k>0,\ x\geq 0,\ y\geq 0$$

Here, *x* is the amount made in-house and *y* is the amount bought from an external source, and C*(x,y)* is the total cost of procurement, which is to be minimized.

We make the following three assumptions:

1. C(*x,y*) is strictly increasing in each of its arguments, keeping the other constant.
2. C(*x,y*) is continuously differentiable to the second order in each argument.
3. $\frac{\partial^2 C}{\partial x^2}+\frac{\partial^2 C}{\partial x^2}>2\frac{\partial^2 C}{\partial x\partial y}$ for all *x,y* in the range *[0, k]*. This is equivalent to assuming that the cost function is strictly quasi-concave.

These assumptions guarantee both the existence and the uniqueness of an interior solution.

It is easy to show that the equilibrium occurs at (x^*, y^*) where the following condition is satisfied:

$$\frac{\partial C(x^*,y^*)}{\partial x}=\frac{\partial C(x^*,y^*)}{\partial y} \qquad (1)$$

We normalize *k=1* so that *x, y* become the proportions made and bought respectively,

and $y^*=1-x^*$.

We will first state a general result that can be used to examine the specific effects of complementarity and constraints. Consider a parameter *t* of the function C*(x,y)* and its effect on the equilibrium x^*: Assume that C*(x,y,t)* is continuously differentiable in *t.*

Differentiating the identity $\frac{\partial C(x^*,y^*,t)}{\partial x}=\frac{\partial C(x^*,y^*,t)}{\partial y}$ with respect to *t,* we get

$\frac{\partial^2 C}{\partial x^2}\frac{dx^*}{dt}+\frac{\partial^2 C}{\partial y\partial x}\frac{dy^*}{dt}+\frac{d}{dt}\left(\frac{\partial C}{\partial x}\right)=\frac{\partial^2 C}{\partial x\partial y}\frac{dx^*}{dt}+\frac{\partial^2 C}{\partial y^2}\frac{dy^*}{dt}+\frac{d}{dt}\left(\frac{\partial C}{\partial y}\right)$, where the second derivatives are taken at (x^*, y^*, t)

$k=1 \ \Rightarrow\ \frac{dy^*}{dt}=-\frac{dx^*}{dt}$. So, we can write:

$$\frac{dx^*}{dt}=\frac{\frac{d}{dt}\left(\frac{\partial C}{\partial x}\right)-\frac{d}{dt}\left(\frac{\partial C}{\partial y}\right)}{-\left[\frac{\partial^2 C}{\partial x^2}+\frac{\partial^2 C}{\partial x^2}-2\frac{\partial^2 C}{\partial x\partial y}\right]}. \qquad (2)$$

Lemma 1: The sign of $\frac{dx^*}{dt}$ depends on the sign of $\frac{d}{dt}\left(\frac{\partial C}{\partial x}\right)-\frac{d}{dt}\left(\frac{\partial C}{\partial y}\right)$; whether x^* increases or decreases with *t* depends on whether the numerator of (2) is negative or positive. Note that this expression is the derivative with respect to the parameter *t* of the difference between the marginal cost of making and marginal cost of buying.

1.1 Definitions: Constraints & Complementarities

Within this framework, we can now define constraints and complementarities.

Denote the marginal rate of transformation by $MRT_{X,Y} \equiv \frac{C_x(x,y)}{C_y(x,y)} \equiv \frac{\frac{\partial C(x,y)}{\partial x}}{\frac{\partial C(x,y)}{\partial y}}$.

Consider three parameters *i, e* and □ that govern the form of the function *C(x,y),* such that $MRT_{X,Y}$ is differentiable in each parameter and:

- $MRT_{X,Y}$ is strictly *decreasing* in *e* for all *x* in *(0, k)*,
- $MRT_{X,Y}$ is strictly *increasing* in *i* for all *x* in *(0, k)*,
- $MRT_{X,Y}$ is *decreasing* with respect to θ uptil some $x^0 \in (0,k)$, and is *increasing* with respect to θ for $x > x^0$

Then, *i* is a *constraint on internal production*, *e* a *constraint on external procurement* and □ denotes the *complementarity* between production and procurement.

To show the intuition, note that at (x^*, y^*),

$\frac{d}{dt}MRT_{X,Y} = \frac{1}{(C_y)^2}\left(C_y\frac{dC_x}{dt}-C_x\frac{dC_y}{dt}\right)=\frac{1}{C_y}\left(\frac{dC_x}{dt}-\frac{dC_y}{dt}\right)$, since $C_x = C_y$.

Since the denominator of (2) is negative, $\frac{dx^*}{dt}$ has the opposite sign as $\frac{d}{dt}MRT_{X,Y}$.

From (2), we can write $\frac{dx^*}{dt} = \frac{C_y\frac{d}{dt}MRT_{XY}}{-\left[\frac{\partial^2 C}{\partial x^2}+\frac{\partial^2 C}{\partial x^2}-2\frac{\partial^2 C}{\partial x \partial y}\right]}$. Since the denominator is negative, the sign of dx^*/dt is opposite of the sign of the derivative of MRT_{XY}.

Thus, we have $\frac{dx^*}{di} < 0$ which makes *i* a constraint on production. Similarly, we have $\frac{dx^*}{de} > 0$ or $\frac{dy^*}{de} = -\frac{dx^*}{de} < 0$, which makes *e* a constraint on procurement. On the other hand, for $x^* < x^0, \frac{dx^*}{d\theta} > 0$ and for $x^* > x^0, \frac{dx^*}{d\theta} < 0$. Thus, an increase in θ "pulls" the optimum towards

some interior allocation- i.e. makes combinations of making and buying superior to doing either alone.

Robustness of P1-P3 to simplifying assumptions

While we have treated them identically, since *e* and *i* pull x^* in opposite directions, one should be careful while interpreting the comparative static results. Since we have $e = i = s$, any comparative static result using *s* assumes that not only both constraints are equally strong, but also that they are being increased equally. We show below that if only one of the constraints increases, Propositions 1 and 2 still hold, but Proposition 3 holds with some qualifications.

$x^* = \frac{e+\theta+\delta}{e+i+2\theta}$. This implies that $\frac{\partial x^*}{\partial \delta} = \frac{1}{e+i+2\theta}$

Therefore, $\frac{\partial^2 x^*}{\partial \theta \partial \delta} = -\frac{2}{(e+i+2\theta)^2} < 0$. Also, $\frac{\partial^2 x^*}{\partial e \partial \delta} = \frac{\partial^2 x^*}{\partial e \partial \delta} = -\frac{1}{(e+i+2\theta)^2} < 0$

Thus, both P1 and P2 hold irrespective of the levels of *e* and *i*. In particular, they do not depend on the assumption that they are equal to some number *s*.

While examining P3, we maintain the assumption that $e = i = s$, but then examine what happens (locally) if only *e* increases, leaving *i* unchanged at *s*, or vice versa.

$$\rho = \frac{(e+\theta+\delta)(i+\theta-\delta)}{(e+i+2\theta)^2} \Rightarrow \frac{\partial \rho}{\partial \theta} = -\frac{1}{e+i+2\theta} - \frac{4(e+\theta+\delta)(i+\theta-\delta)}{(e+i+2\theta)^3}$$

First note that if $e = i = s$, then $\frac{\partial \rho}{\partial \theta} = \frac{\delta^2}{8(s+\theta)^3} > 0$.

Now, it can be shown that $\frac{\partial^2 \rho}{\partial e \partial \theta} = -\frac{1}{(e+i+2\theta)^2} - \frac{4(i+\theta-\delta)}{(e+i+2\theta)^4}\left[(e+i+2\theta) - 3(e+\theta+\delta)\right]$.

Using $e = i = s$, we get $\frac{\partial^2 \rho}{\partial e \partial \theta} = \frac{2\delta(s+\theta) - 3\delta^2}{4(s+\theta)^4}$, and $\frac{\partial^2 \rho}{\partial i \partial \theta} = \frac{-2\delta(s+\theta) - 3\delta^2}{4(s+\theta)^4}$

Therefore, $\frac{\partial^2 \rho}{\partial e \partial \theta} < 0$ if and only if $\delta < 0$ or $\delta > \frac{2}{3}(s+\theta)$. On the other hand, if $0 < \delta < \frac{2}{3}(s+\theta)$, then $\frac{\partial^2 \rho}{\partial e \partial \theta} > 0$. Another way to say this is that $\frac{\partial^2 \rho}{\partial e \partial \theta} < 0$ if and only if $x^* < 0$ or $x^* > 5/6$. Otherwise, $\frac{\partial^2 \rho}{\partial e \partial \theta} > 0$.

In the same way, $\frac{\partial^2 \rho}{\partial i \partial \theta} < 0$ if and only if $\delta > 0$ or $\delta < -\frac{2}{3}(s+\theta)$. On the other hand, if $0 > \delta > -\frac{2}{3}(s+\theta)$, then $\frac{\partial^2 \rho}{\partial i \partial \theta} > 0$. Another way to say this is that $\frac{\partial^2 \rho}{\partial i \partial \theta} < 0$ if and only if $x^* > 0$ or $x^* < 1/6$. Otherwise, $\frac{\partial^2 \rho}{\partial i \partial \theta} > 0$.

Thus, the negative interaction between constraints and complementarities holds for each constraint separately only if x^* is very small or very large, which happens when either δ is sufficiently large in absolute value or when s and θ are sufficiently small. Put differently, proposition 3 then holds only near the corner solutions- "nearly" all-make or buy.

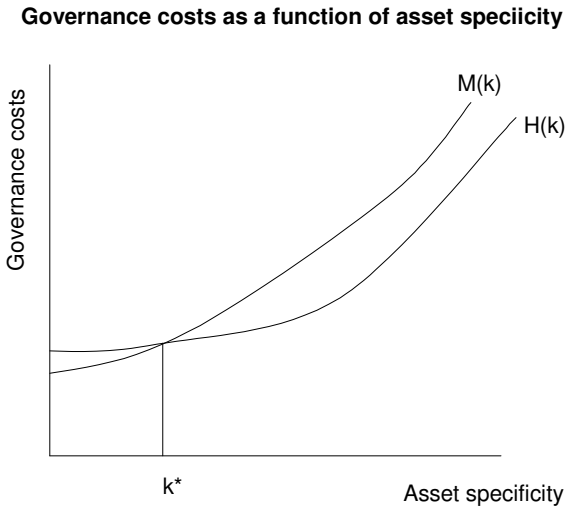

Figure 1

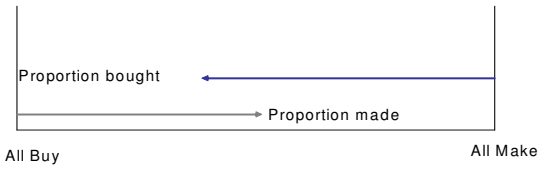

Figure 2

Concept	Key mechanism	Manifestations	Effect	Impact on opt sourcing strat
Incentive Complementarities	Competition	• Threat of backward integration/outsourcing • Superior information on costs/prices & performance measurement • Benchmarking and "ratcheting" of performance	Improved incentives to perform for both internal and external suppliers	• Encourage plural sou • Weakens link bet transactio hazards internal procureme
Knowledge Complementarities	Collaboration	• Distinct kinds of innovation by internal and external suppliers	Improved competence of both internal and external suppliers	• Encourage plural sou • Weakens t link betwe transactio hazards an internal procureme
Constraints: Limits to Scale	Scale Diseconomies	• Coordination complexity and weakened incentives	Limits to internal procurement	• Encourage plural sou • Weakens t link betwe transactio hazards an internal procureme
Constraints: Barriers to exit	Lock-ins	• Commitment/reputation lock ins • Bargaining power of unions •	Limits to external procurement	• Encourage plural sou • Weakens t link betwe transactio hazards an internal procureme

Table 1: Complementarities and Constraints: An Overview

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